

Supply Chain Network Design Considering Customer Service Level

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Abstract

The supply chain network consists of suppliers, warehouses, distribution centers, and retail outlets which provide the flow of material and products. Determining the location of the facilities and warehouses, determining the appropriate number of warehouses, determining which products will be received by which customers and determining the size of each warehouse are strategic decisions. Due the high competition in businesses, corporations have to enhance their service level to be able to respond their customers' needs and wants quickly and effectively. For this reason, the aim of the study is to make warehouses open in appropriate locations at high, medium and low service level by minimizing operation, transportation, inventory holding and distribution costs. In this paper, we have developed an analysis procedure for the location of DCs that integrates facility costs, inventory costs, transportation cost and service responsiveness consider a multi-echelon service parts logistics system with multi products and number of warehouses via set covering model. This model, which tackled a supply chain composed of the three stages on the brink of suppliers, facilities, warehouses and customers, includes a mathematical structure with multi products and mixed integer programming. Cplex 12.2 solver of GAMS 23.5. program is used in this study. As a result, production facilities opens in Eskisehir, Istanbul, Kayseri and Erzurum cities, and 17, 10 and 6 warehouses runs at high, medium and low service level respectively. There will be a tradeoff between inventory and transportation costs. If we want to force the opening of warehouse in some cities, we will see total and incurred costs.

Keywords

Distribution Center, Service Level, Supply Chain Network Design.

1. Introduction

The logistics network consists of suppliers, warehouses, distribution centers and retail outlets as well as raw materials, work-in-process inventory, and finished products that flow between the facilities. Network configuration may involve issues relating to plant, warehouse and retailer location. Determining the appropriate number of warehouses, determining the location of each warehouse, determining the size of each warehouse, allocating space for products in each warehouse, determining which products customers will receive from each warehouse are key strategic decisions (Simchi-Levi and Kaminsky, 2003):

A good network design provides to achieve one firm's strategic objectives. In supply chain network design, business managers need warehouses or distribution centers in order to deliver finished product for customer premises. The numbers and location of facilities, the assignments of products between warehouses and customers, the capacity of distribution centers and cross-docking points in network design process are very important functions. Targets should be determined by the level of customer service and stock levels of distribution centers.

Customer service presented effectively in companies is preliminary important factor for creating demand and increasing customer's satisfaction. Service level utilizes in order to measure system performance of inventory in supply chain and inventory management. There are several definitions in literature as well as practically. Also, there may be trade-off between costs and service level. If we would like to increase customer service level we should use information and available supply chain network and decrease stocks, production costs and distribution costs. The more effective customer service, the more retail ability. Indeed, retailer's ability is to meet rapidly to customer demands.

There are many papers and studies about supply chain, logistic network design and hub locations in literatures as shown at Table 1.

Table 1. The review of supply chain network problems

Authors (year)	Type of problem	The result of study
Cohen and Lee (1989)	Deterministic, mixed integer and linear global supply chain plan	Maximize the after tax profits for manufacturing plants and distribution centers and at the same time assigning the material meets and all products.
Pirkul and Schilling (1991)	Set Covering Problem with capacity	Trying to meet demands for maximum number of customers and optimal number of facility locations.
Adenso-Diaz and Rodriguez. (1997)	Maximal covering location problem	Location of ambulances in the province of Leo'n, Spain. With 25 ambulances, almost 99.5% of the population can be covered within 25 minutes.
Alminana and Pastor. (1997)	Set covering problem	The method presented here is an improvement of Lopes and Lorenas' (1994) heuristic method for set covering problems. It combines Lagrangean relaxation and surrogate relaxations.
Melkote and Daskin (2001)	Optimization facility locations and distribution network.	Provided to find the least total cost and best location places with 40 nodes and 160 spokes in a case study.
Berman and Krass (2002)	Generalized Maximal Covering Location Problem	Tests on problems between 20 and 400 nodes with up to 5 levels of coverage show that the greedy algorithm performs very well but that CPLEX has trouble solving problems.
Marinov and Serra (2002)	Location-Allocation of Multiple-Server Service Centers with Constrained	Models are solved using heuristic concentration with a Teitz and Bart exchange algorithm used in each of the two phases of the algorithm. The algorithm is tested on Swain's 55 node network. The algorithm did not always find the solution that also minimizes the demand-weighted distance.
Daskin (2002)	Non linear integer programming model	Determined to optimal number of distribution centers, found the facility zones and ensured to assign customers to servicing facilities (retailers).
Espejo et al. (2003)	Hierarchical Covering Location Problems	There are three types of coverage distances, one for the low-level service at the low-level facility, and one each for the low- and the high-level service at the high level facility. The problem is performed Lagrangean and Surrogate relaxation.
Tan and Kara (2007)	The Latest Arrival Hub Covering Model	The most quickly and reliability cargo transport in 24 hours with Integer mathematical problem.
Ross and Jayaraman (2008)	Traditional simulated annealing with Tabu Search	Generating near optimal distribution system design by utilizing the simulated annealing methodology. The model is characterized multiple product families, central manufacturing plant, multiple cross docking and distribution center sites, and retail outlets. New heuristics solution procedures for the location of cross docks and distribution centers in supply chain network design.
Bachlaus et al. (2008)	SCOR model. Hybrid Taguchi-Particle Swarm Optimization	Find the number of distribution centers and cross docks to be opened for the demand of each customer zones, identify the best suppliers and plant on the basis of selection criteria, and assign cross dock to customer throughout the supply chain.
Ghodsi et al. (2010)	Single allocation set covering problem with capacity constraint.	Find hub locations and spoke and node points with capacity facilities and minimizing transportation coat
Davari et al. (2011)	Fuzzy maximal set covering location problem	Using Tabu search (-%1.35 according to best solution) and fuzzy simulation heuristic by considering to fuzzy travel time

When papers are taken into account, supply chain network problems have been designed occurred with multi echelon and multi product, solved with available data and compared with such a heuristic method. The purpose of these mathematical models is to minimize total costs and to make strategically and operational decisions in order to provide effective production and distribution system. On the other hand, studies have been done to provide the best distribution systems for finding facility locations and numbers, determine customer-warehouse and customer cross docks assignments through the supply chain.

If papers are examined, there are very few applications that taken into account service level in supply chain network design. Maximum customer service level is implementing very rarely in companies. Servicing for large amount of customer is important regardless to ability to service and total cost. From this respect, the contribution of this paper in the literature is: the mathematical model have been developing to help making strategically and tactical decisions with service level concept for multi echelon logistic network design. This network is a class of three echelon of supply chain with multi product and includes suppliers, plants, distribution centers and customer zones. The purpose of this notice is to identify the optimal number of facility and facility locations by covering maximum amount of customers and by taking in to account service level variability (low, medium, high) in multi echelon supply chain network design problem. Service levels are compared by changing distance constraint in-between warehouses and customers.

2. Set Covering Model

Set covering problems is the simplest of facility location models. The aim of set covering problem is to find a minimum cost set of facilities so that every demand node is among a finite set of candidate facilities. In the set covering model, we attempted to find the locations of the minimum number of facilities needed to cover all demand nodes. The number of facilities needed to cover all demand nodes within the exogenously specified distance was prohibitively large. In addition, the set covering model failed to account for the fact that the demands at the nodes differ. To alleviate these problems, we formulated and discussed the maximum covering location problem. In that model, we associated a demand level with each demand node and found the locations of a fixed number of facilities to maximize the number of covered demand (Daskin, 1995).

Another possibility that ensures a predefined service standard is to choose the largest allowable distances between any customer and his closest facility. The objective of the location set covering model is to minimize the number of facilities that are needed to provide service to all customers. In fact, service standards are often stipulated as part of the legislation associated with the provision and funding of such services. In such cases, a covering based model is often the most appropriate choice for location modeling (ReVelle et al, 2008).

Formally, demands at a node $i \in I$ are typically said to be covered by a facility at candidate site $j \in J$ if the distance (or travel time) between the nodes is less than some critical distance D_c . Other definitions of coverage are also possible. If node $i \in I$ can be covered by a facility at candidate site $j \in J$, then we set $a_{ij}=1$, otherwise $a_{ij}=0$. We also let $N_i = \{j : a_{ij}=1\}$ i.e., N_i is the set of all candidate sites that can cover demand node $i \in I$. With this additional notation, we can formulate the location set covering model, originally proposed by Toregas et al. (1971), as follows:

$$\begin{aligned} \text{Min} \quad & \sum_j X_j & (1) \\ \text{s.t} \quad & \sum_i X_j \geq 1 & \forall i \\ & X_j \in \{0,1\} & \forall j \end{aligned}$$

The objective function (1) minimizes the number of facilities that are opened. Constraints (2) presents $\{i \in I\}$ at least one facility must be located within the set N_i of candidate facility sites that can cover the node that for each demand nodes. Constraints (3) are the integrality constraints.

We need to distinguish between problems in which the facilities can be located anywhere on the network and problems in which facilities can be located only on the nodes of the network. If facilities can be located only on the nodes and we can locate only one facility ($P=1$), either node is optimal. This is known *P-center problem or a minimax problem*. If we locate anywhere on the network, locating the single facility midway between nodes A and B is optimal. This is known *maximum covering problems* (Daskin, 1995)

3. Mathematical Formulation

The main aim of this supply chain network model is to determine warehouses and facility locations and numbers for company that served all customers living in Turkey with multi products demands. For this kind of firm that target to deliver all products to Turkey with desired time and amount of. Each other countries destinations got from highway map as a kilometer. Distribution centers have to be opened in Turkey's some points in order to reach all products from warehouse to demand points. A mathematical model was formulated to define distribution sites depending on service level that include low, medium and high. The purpose as explained before is to provide the best service by establishing optimum number of warehouse sites regardless to specific service level in Turkey. The problem is described for a flexible supply chain contained three raw materials, three suppliers and two types of products under the material requirement.

3.1. Assumptions

A multi echelon, multi commodity supply chain network design problem considering customer service level assumptions are described in the following items.

- Production cost in manufacturing plants shows difference according to product variations.
- Demand points are taken as the provincial centers of Turkey.
- Model has multi products and multi echelon structure.
- Customers' demands are well known and demands are special for each customer and product.
- Customers demand for products is satisfied by open only one warehouse.
- The suppliers and plants total capacities are known before and they are restricted.
- Transportation costs from suppliers to production plants, from production plants to distribution centers and from distribution centers to customers were given in formulation.

3.2. Indexies and Notations

Indexies

$i=1,2,\dots,i$	product sets
$J=1,2,\dots,j$	distribution sets
$c=1,2,\dots,c$	customer sets
$P=1,2,\dots,p$	production facility sets
$s=1,2,\dots,s$	supplier sets
$r=1,2,\dots,r$	raw material sets

Notations

$WOPC_j$: annual fixed cost for warehouse j
$POPC_p$: annual fixed cost for plant p
SPC_{spr}	: unit transportation cost from supplier s to plant p for raw material r
PWC_{pji}	: unit transportation cost from plant p to warehouse j for product i
WCC_{jci}	: unit transportation cost from warehouse j to customer c for product i
PC_{pi}	: unit production cost for product i at plant p
h_i	: annual holding cost for product i
m_{cj}	: distance between customer c and warehouse j
ATW_j	: annual amount of throughput from warehouse j
CD_{ci}	: demand of customer c for product i
$SCAP_{sr}$: supplier capacity of supplier s for raw material r
$PCAP_p$: production capacity of plant p

m : safety factor

Variables

SS_{ij} : amount of safety stok of warehouse j for product i

SPQ_{spr} : quantity of raw material r transported from supplier s to plant p

PQ_{pi} : quantity of product i produced plant p

PWQ_{pji} : quantity of product i transported from plant p to warehouse j

WCQ_{jci} : quantity of product i transported from warehouse j to customer c

$$X_p = \begin{cases} 1 & \text{if lant } p \text{ is open} \\ 0 & \text{otherwise} \end{cases}$$

$$Y_j = \begin{cases} 1 & \text{if warehouse } j \text{ is open} \\ 0 & \text{otherwise} \end{cases}$$

$$Z_{cj} = \begin{cases} 1 & \text{if customer } c \text{ assigned to warehouse } j \\ 0 & \text{dd} \end{cases}$$

3.3. Model

$$\text{Min}Z = \left(\sum_{s=1}^S \sum_{p=1}^P \sum_{r=1}^R SPC_{spr} SPQ_{spr} \right) + \left(\sum_{p=1}^P POPC_p X_p + \sum_{p=1}^P \sum_{i=1}^I PC_{pi} PQ_{pi} + \sum_{p=1}^P \sum_{j=1}^J \sum_{i=1}^I PWC_{pji} PWQ_{pji} \right) + \left(\sum_{j=1}^J WOPC_j Y_j + \sum_{i=1}^I \sum_{j=1}^J (SS_{ij} h_i) \right) + \left(\sum_{j=1}^J \sum_{c=1}^C \sum_{i=1}^I WCC_{jci} WCQ_{jci} \right) \quad (4)$$

$$\sum_{j=1}^J Z_{cj} = 1 \quad \forall c \quad (5)$$

$$\sum_{i=1}^I PQ_{pi} \leq PCAP_p X_p \quad \forall p \quad (6)$$

$$Z_{cj} * m_{cj} \leq \beta_i - \beta_{1-i} \quad (7)$$

$$SS_{ij} \geq m * CD_{ci} * Y_j \quad \forall c, i, j \quad (8)$$

$$\sum_{c=1}^C \sum_{i=1}^I CD_{ci} Z_{cj} \leq ATW_j Y_j \quad \forall j \quad (9)$$

$$Z_{cj} \leq Y_j \quad \forall c, j \quad (10)$$

$$\sum_{j=1}^J WCQ_{jci} = CD_{ci} \quad \forall c, i \quad (11)$$

$$\sum_{p=1}^P \sum_{i=1}^I PWQ_{pji} \geq \sum_{c=1}^C \sum_{i=1}^I WCQ_{jci} \quad \forall j \quad (12)$$

$$\sum_{p=1}^P SPQ_{spr} \leq SCAP_{sr} \quad \forall r, s \quad (13)$$

$$X_p, Y_k, Z_{cj} = \{0,1\} \quad (14)$$

$$PQ_{pi}, SPQ_{spr}, PWQ_{pkl}, WCQ_{jci} \geq 0 \quad (15)$$

The objective function (4) minimizes cost to transport raw materials from suppliers to production plant, fixed costs to open production plant, production cost and transportation cost to warehouses, fixed cost to open warehouse, holding product cost and cost to transport from warehouse to customers. The constraint (5) provides each customer to be assigned to only one warehouse. Constraint (6) ensures the total production quantity of products to be

The case in which ten warehouses opened at middle service level with 300 km distance constraint was exhibited in Fig. 2. It is seen that Sivas province get service only its own warehouse. At the same time, although warehouses are opened in some cities, it is founded that these cities get services from the warehouses in different cities. In spite of getting a huge cost advantage with 300 km distance constraint, it is seen that decrease in service level and requirement to make opened warehouses give services to more demand points cause increase in coverage area and transportation costs.

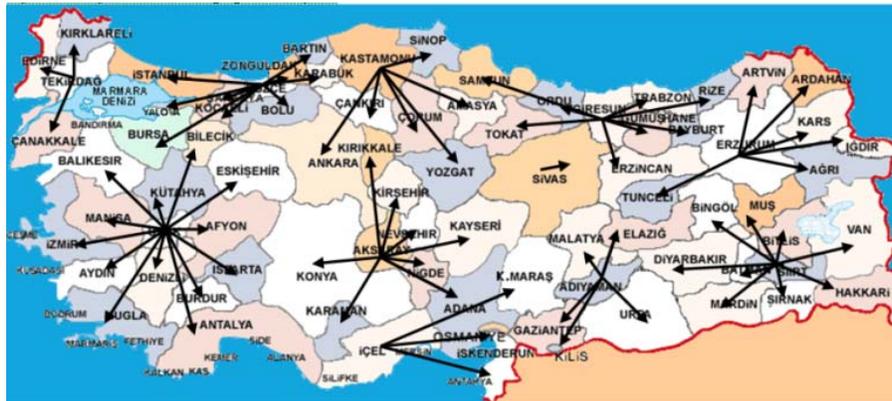


Figure 2: Opened locations and service points under the 300 km distance constraint

The case in which six warehouses opened at low service level with 400 km distance constraint is exhibited in Figure 3. As it is seen that the number of their warehouses decreases and they are forced to serve more places. The most outstanding thing in figure is, besides giving services to more western provinces according to its location, the warehouses founded in Isparta province also give services to Konya city. This case causes a vehicle routing problem. Because, if vehicles depended on demand are scheduled, it is required to provide three different vehicles for Konya city whose demand is 60 units. This can be a problem for managers. Besides all, Tekirdağ province's performance in order to serve to İstanbul and beyond this city increases the transaction costs considerably.

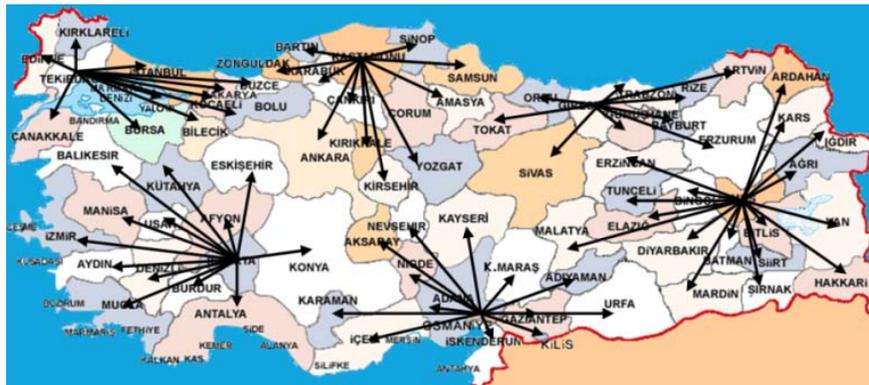


Figure 3: Opened locations and service points under the 400 km distance constraint

As a result of interviews with company officials that obtaining the most appropriate solution to solve the model not only the distance between cities, at the same time; to reduce the demand-weighted traveling path high demand cities, high population of cities, to ensure ease of transport and land located cities on the roads, have energy, labor opportunities and some cities have company's regional warehouse at the moment by taking an account to want to make cost comparison. In this case, the decision was taken that a warehouse also must be opened in Ankara, Bursa,

İzmir and Kocaeli as well as İstanbul and Kayseri at the high level of service level under the 200 km distance in company.

Other cities which are considered to open warehouse are added to the model by forcing the model. In this case, the number of opened warehouses and occurred costs are shown in the Table 3.

Table 3. Opened the number of warehouses and costs by forcing the model under 200 km distance constraint

Cases	Number of warehouse opened	Total cost	Cost incurred
Model without forcing	17	104.515	
Ankara included	19	158.915	54.400
İstanbul included	18	131.835	27.320
Bursa included	17	104.515	0
İzmir included	18	131.775	27.260
Kayseri included	17	104.575	60
Kocaeli included	18	131.775	27.260
Kayseri and İzmir included	18	494.835	27.320
Ankara and İstanbul included	19	159.095	54.580
Ankara, İstanbul, Bursa, İzmir and Kayseri included	20	186.415	81.900

The model was established initially by forcing it was decided to open warehouses in some cities above mentioned reasons. But, because of the cost opened each stores are not known the sensitivity analysis is done for each of them and a comparison of the results are evaluated according to the first position. When the table examined, the model was solved separately thought opening warehouses in big demand cities like Ankara and İstanbul, 19 and 18 warehouses are opening respectively in Turkey. Incurred costs are 54.400 € and 27.320 €. Instead of this case, if the model are solved again opening warehouses in Ankara and İstanbul together will be 19 and incurred cost become 54.580 €. Thus, one of them is a capital of Turkey (Ankara) and one of the other (İstanbul) have the biggest demand because of population have distribution center. So they provide supply chain network more effective

4. Conclusion

In this paper, we have developed an analysis procedure for the location of DCs that integrates facility costs, inventory costs, transportation costs and service responsiveness consider a multi-echelon service parts logistics system with multi products and number of warehouses. The problem is to determine the best base service levels at all local warehouses that meet all the distance-based service level constraints at minimal costs. Using this procedure, decision makers can easily understand the service-cost trade-offs that are available, so that best location decisions can be obtained. Because of this reason a mathematical model is developed to solve and satisfy customers need. This application is occurred to the food industry with real cost and distance units

Returning to the main objective of this research, we tried to understand how service level constraint effects supply chain network design. Further analysis with different service levels for each warehouse, and for different items, can be achieved without significant additional complexity. Service level or probability for other type of constraints, traditionally modeled with Chance Constrained Programming, can be optimized based on proposed iterative equilibrium conditions.

Real life problems, time, cost and distance based coverage criteria are not always easy to predict. A new model can be obtained in this study by making fuzzy linear model because of indefinite and uncertain distance constraint between customers and warehouse. This can be disadvantages of this study.

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